Digital Image Correlation (D.I.C.) Techniques Applied to Large Scale Rocket Engine Testing

National Aeronautics and Space Administration

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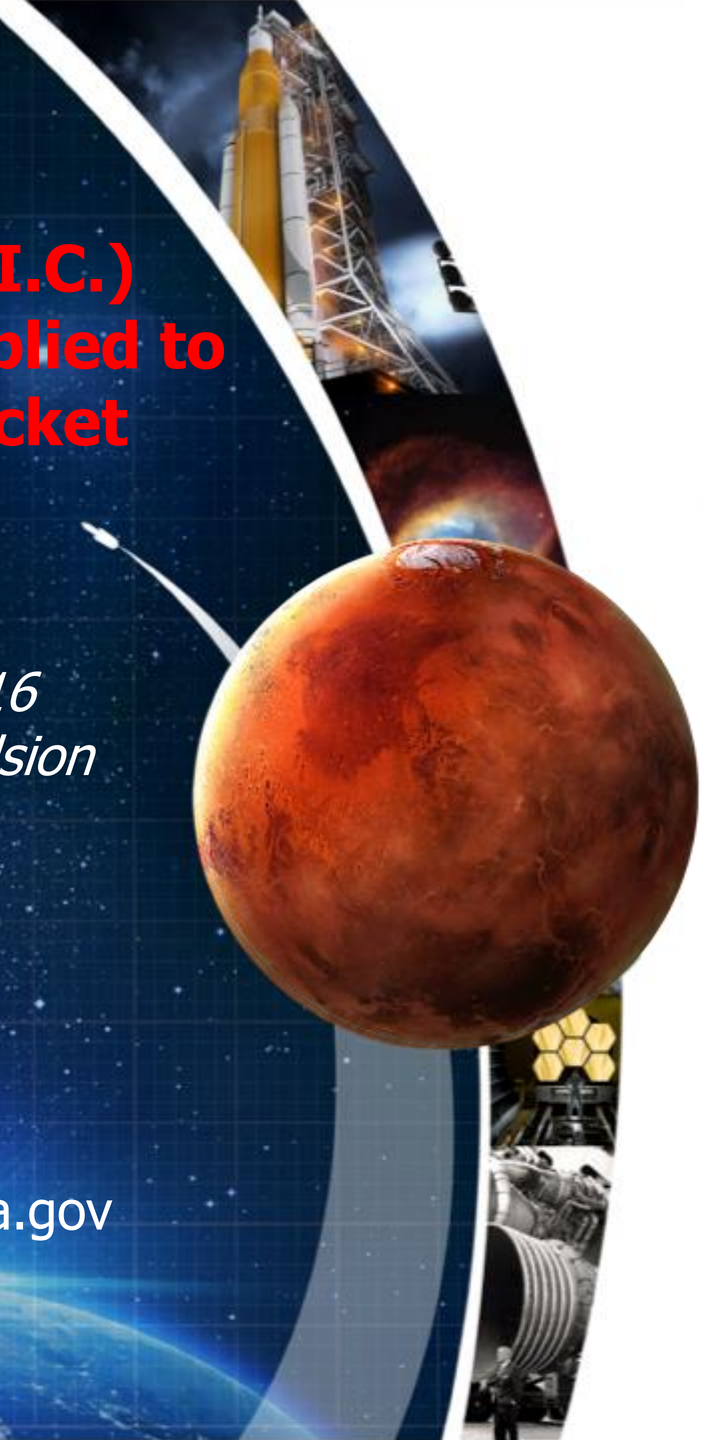

MARSHALL
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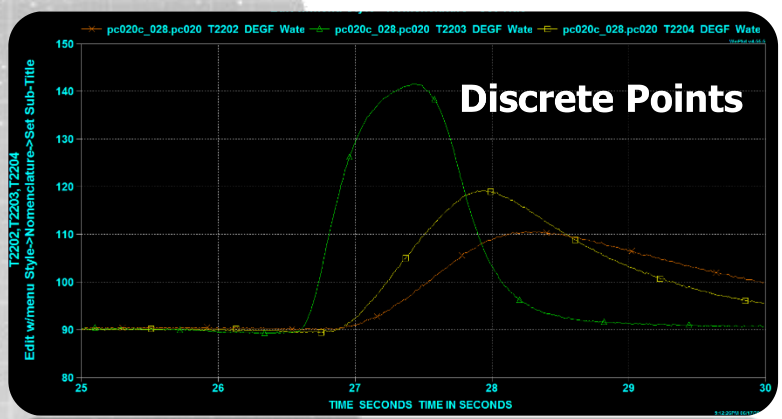
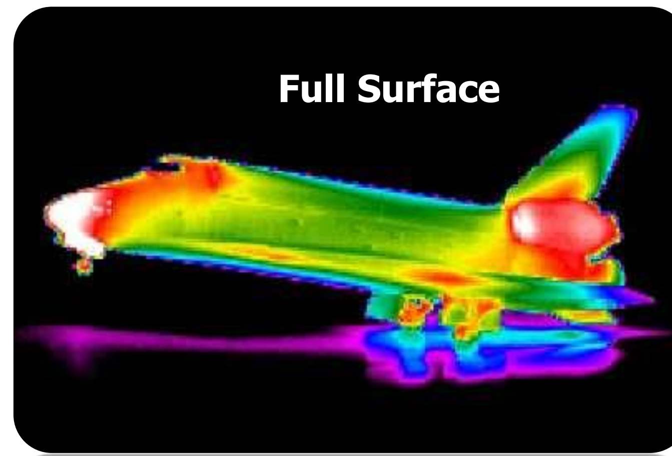
Motivation for Technology

- Subscale and Full-scale testing requires expensive and labor intensive instrumentation to better understand hardware performance
  - Design Modifications and Performance Predictions based on “discrete” point instrumentation
    - Thermocouples, Pressure Transducers, Accelerometers, Strain Gages
- **Challenge: Measure highly dynamic elevated temperature components**

Full Surface **>** Point
IR **>** Thermocouple
D.I.C. **>** Strain Gage

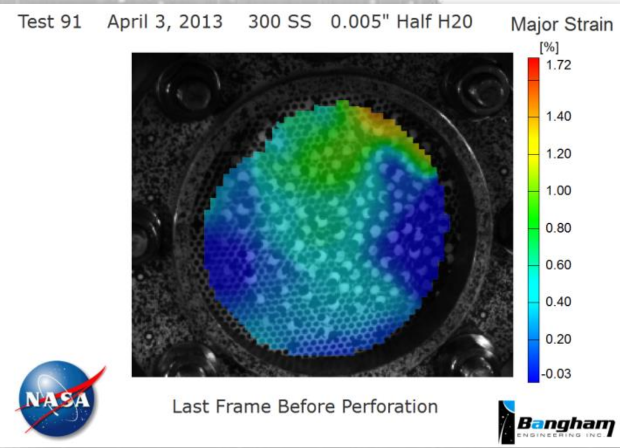
D.I.C. = Digital Image Correlation



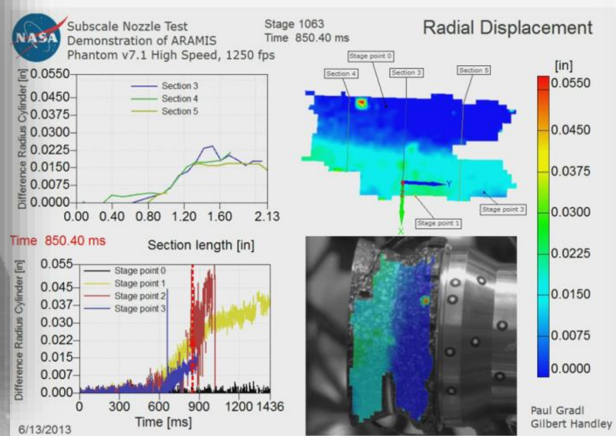


Goal: Augment Traditional Gages to gain a better understanding of hardware and environment loads to design more efficient components and systems

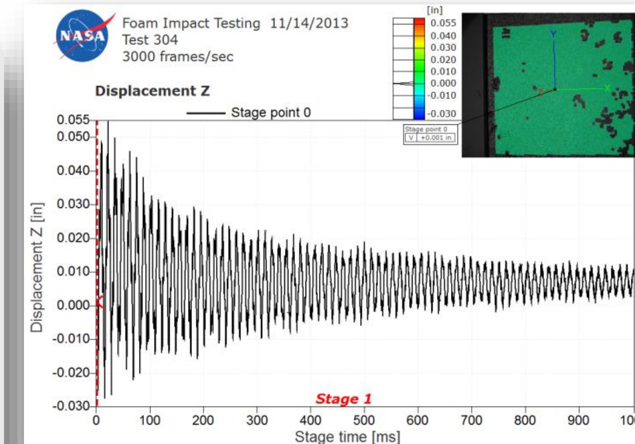
Applications and Development work for Digital Image Correlation at NASA



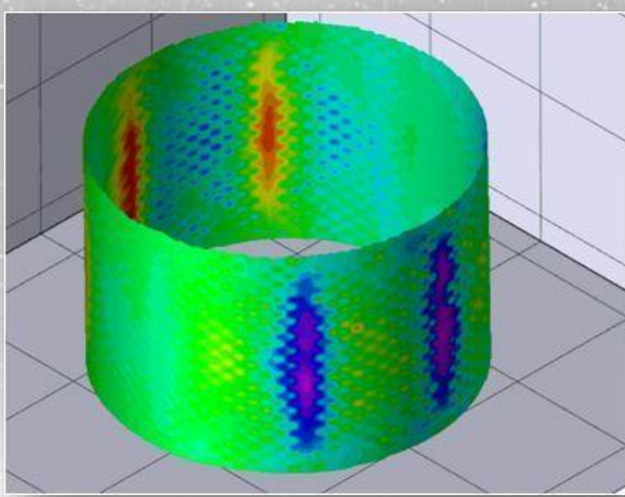
Blast Pressure Wave Tracking at 70,000 fps



Subscale Nozzle Displacements at 1700F

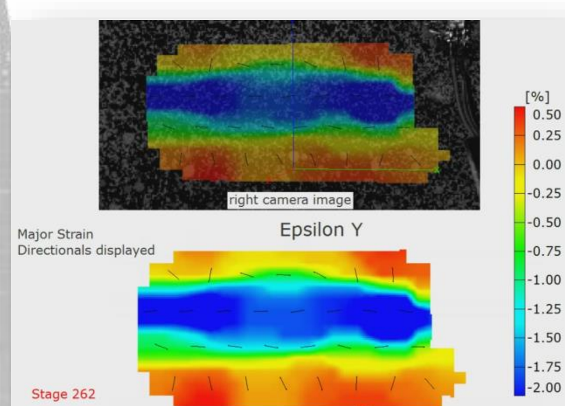


Debris Impact Testing – Eliminated Strain Gages

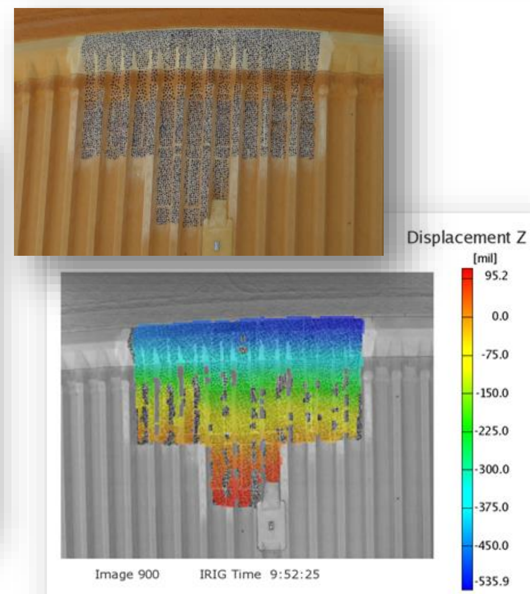


Full-Field Strain and Displacements of 18-ft Dia Tank

Ref: Todd Boles, MSFC/ET30



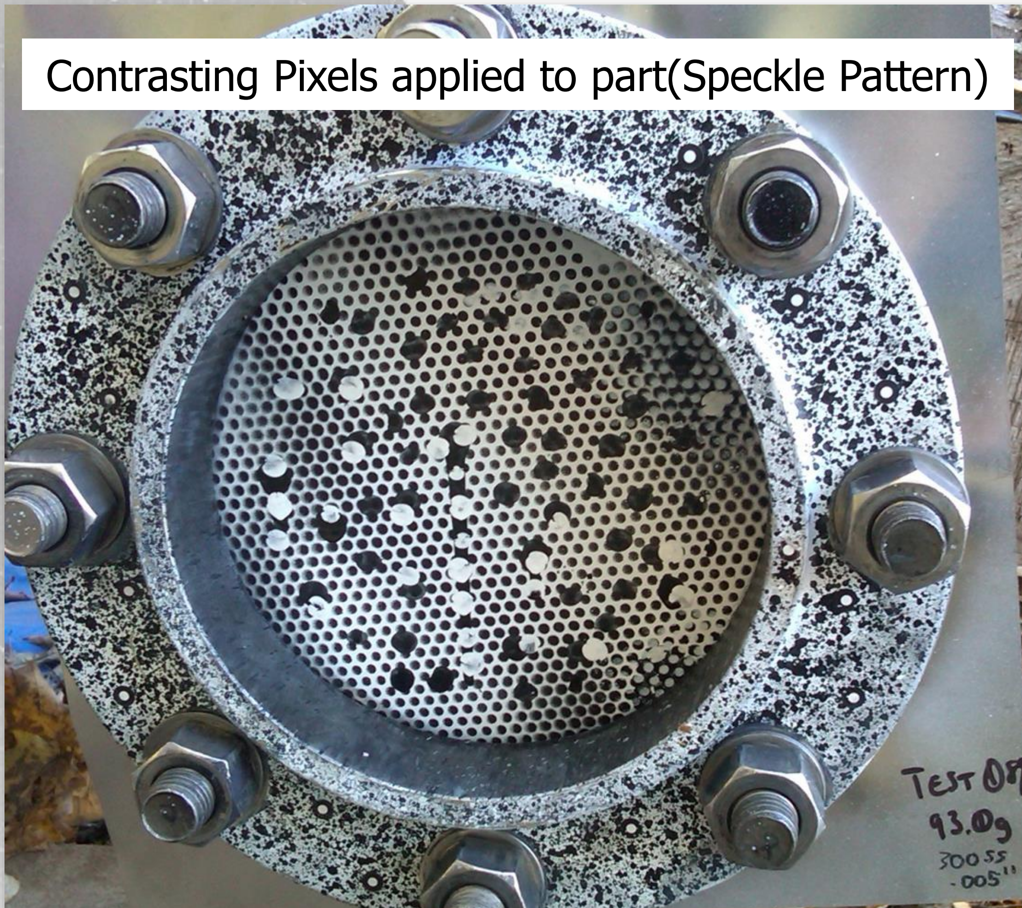
High Speed Composite Compression – Direct Application of Major Strain



ET (on Pad) Cryo tanking test to observe stringer displacement

What is Digital Image Correlation?

Contrasting Pixels applied to part(Speckle Pattern)



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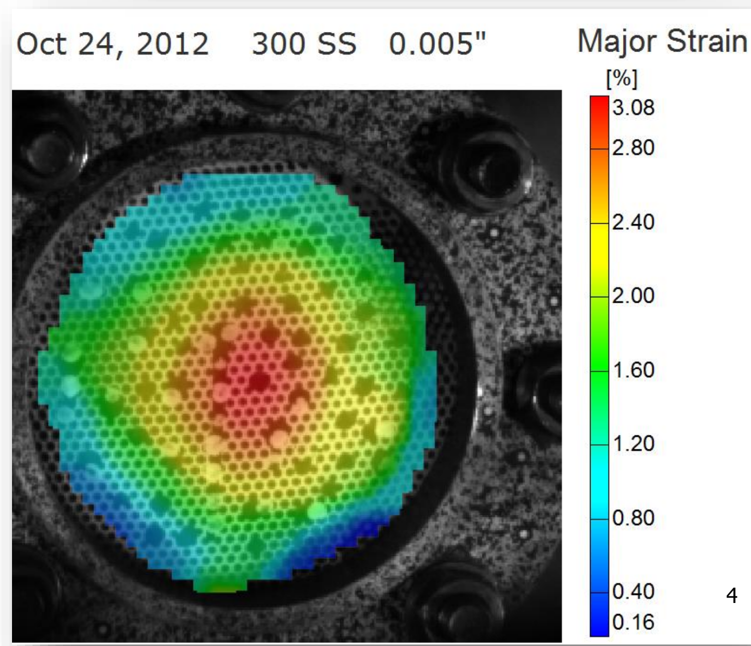
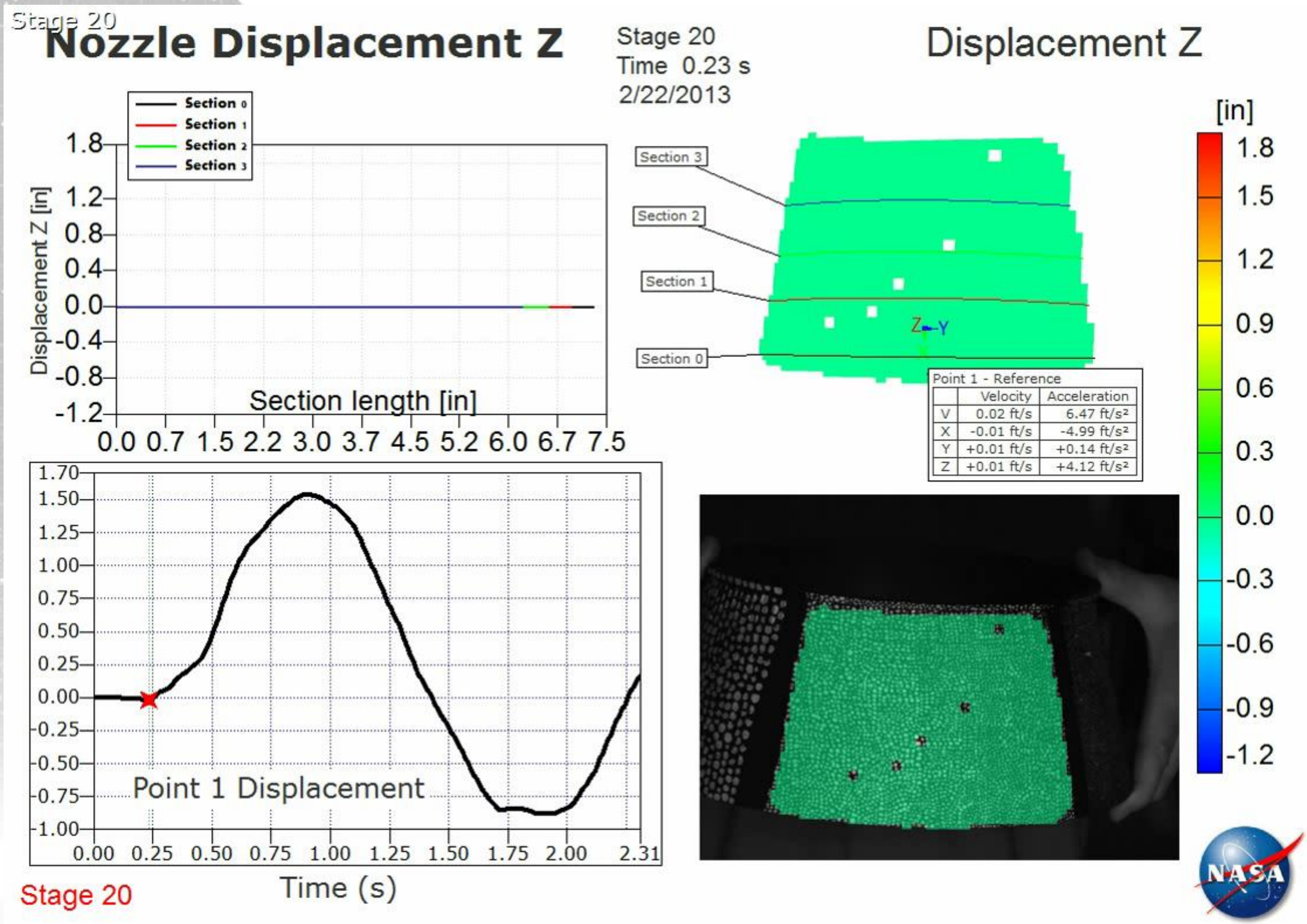
Stereo Camera Triangulation

Photo Provided by: Tim Schmidt / Trilion

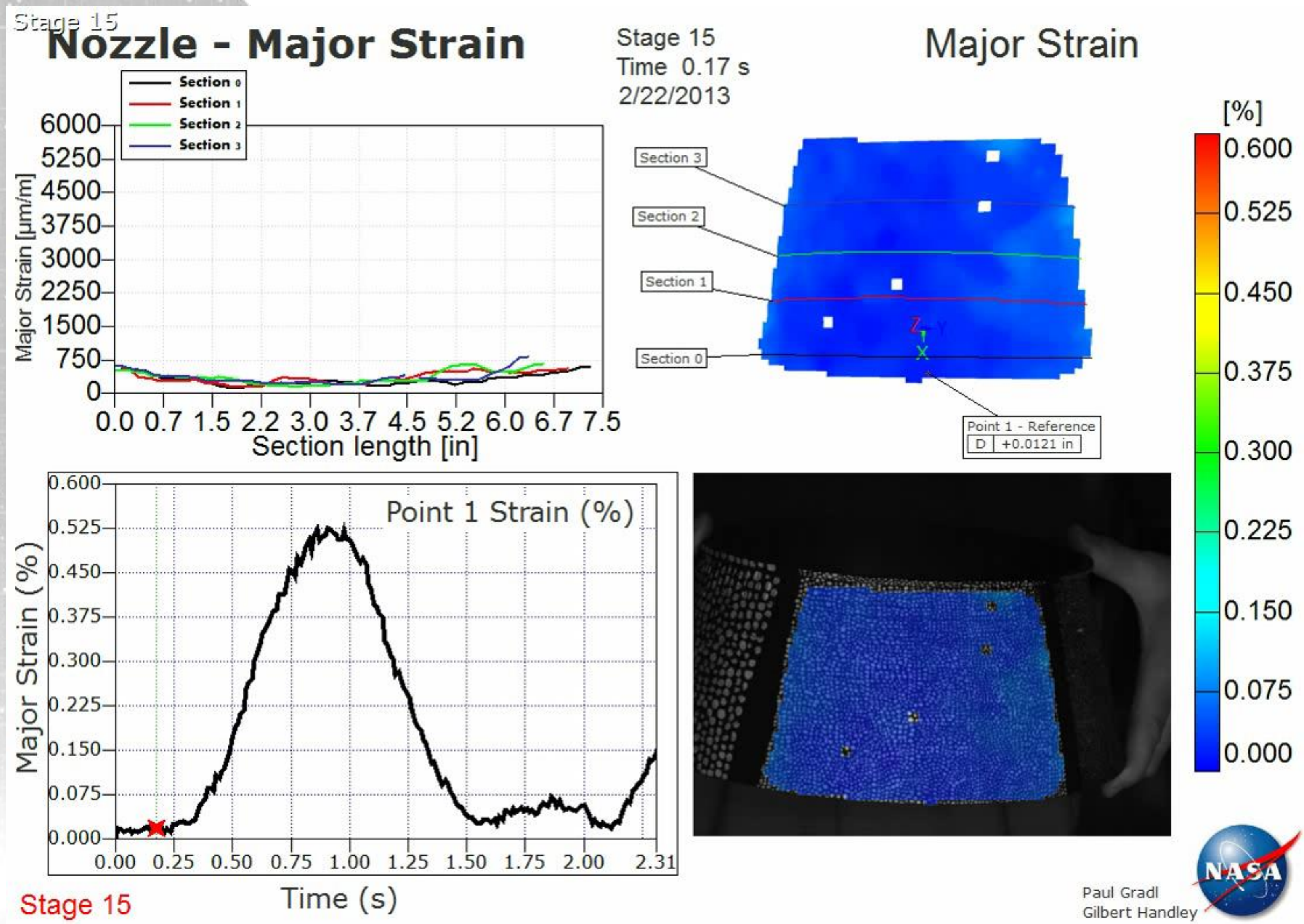


= Full Field Displacement and Strain Measurements

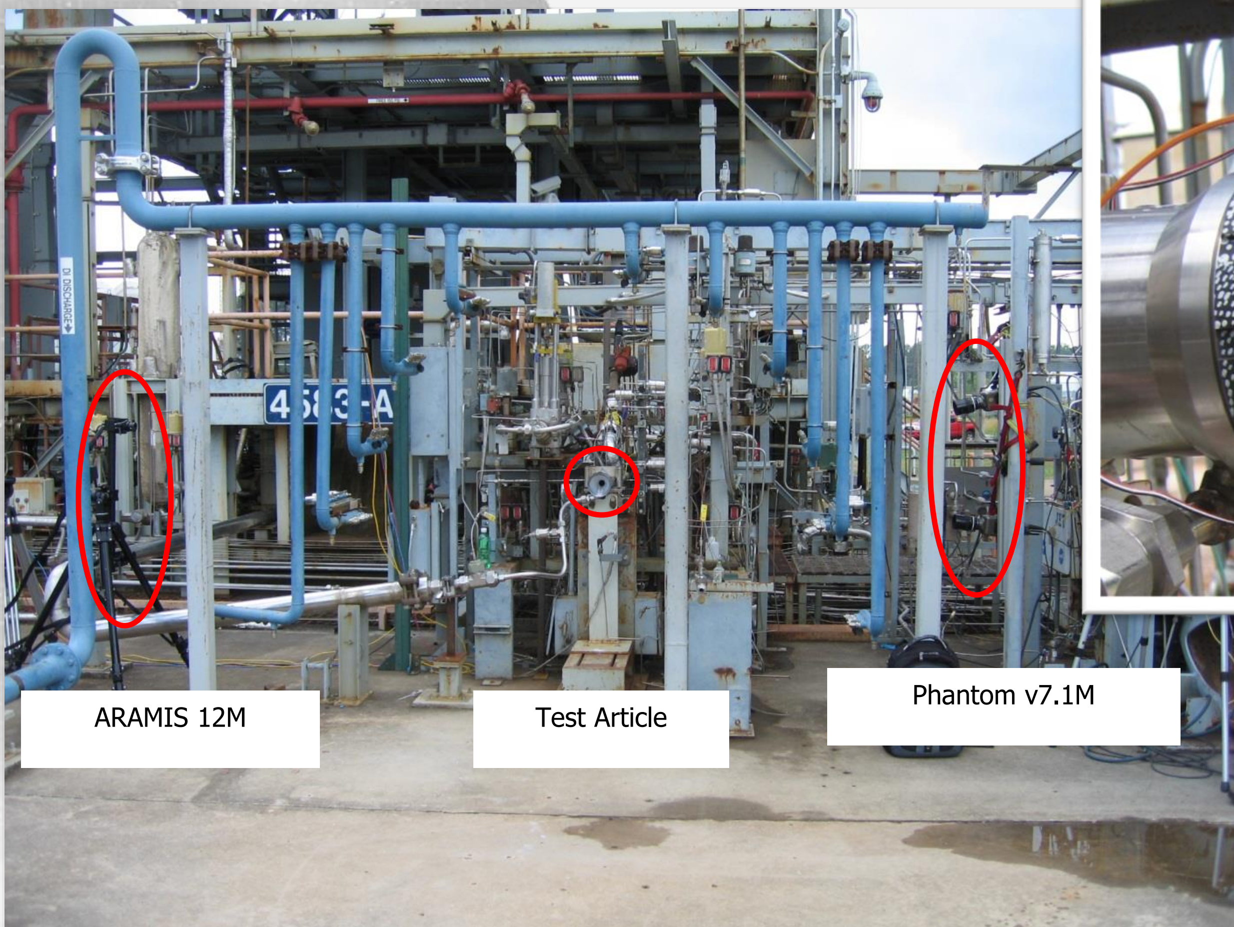
ARAMIS Lab Experiments – Displacement

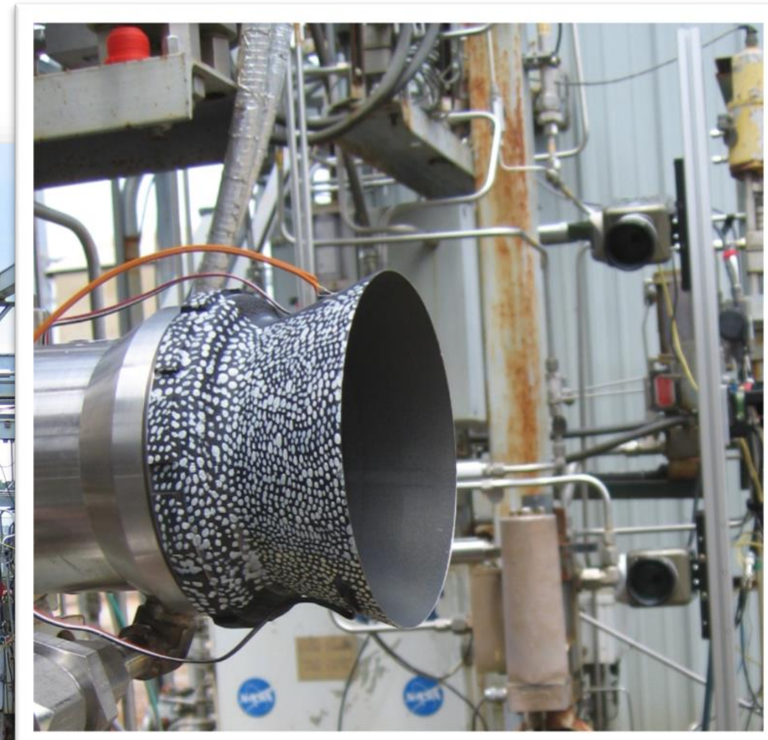


ARAMIS Lab Experiments – Principal Strain



Subscale Hot-fire Nozzle Testing

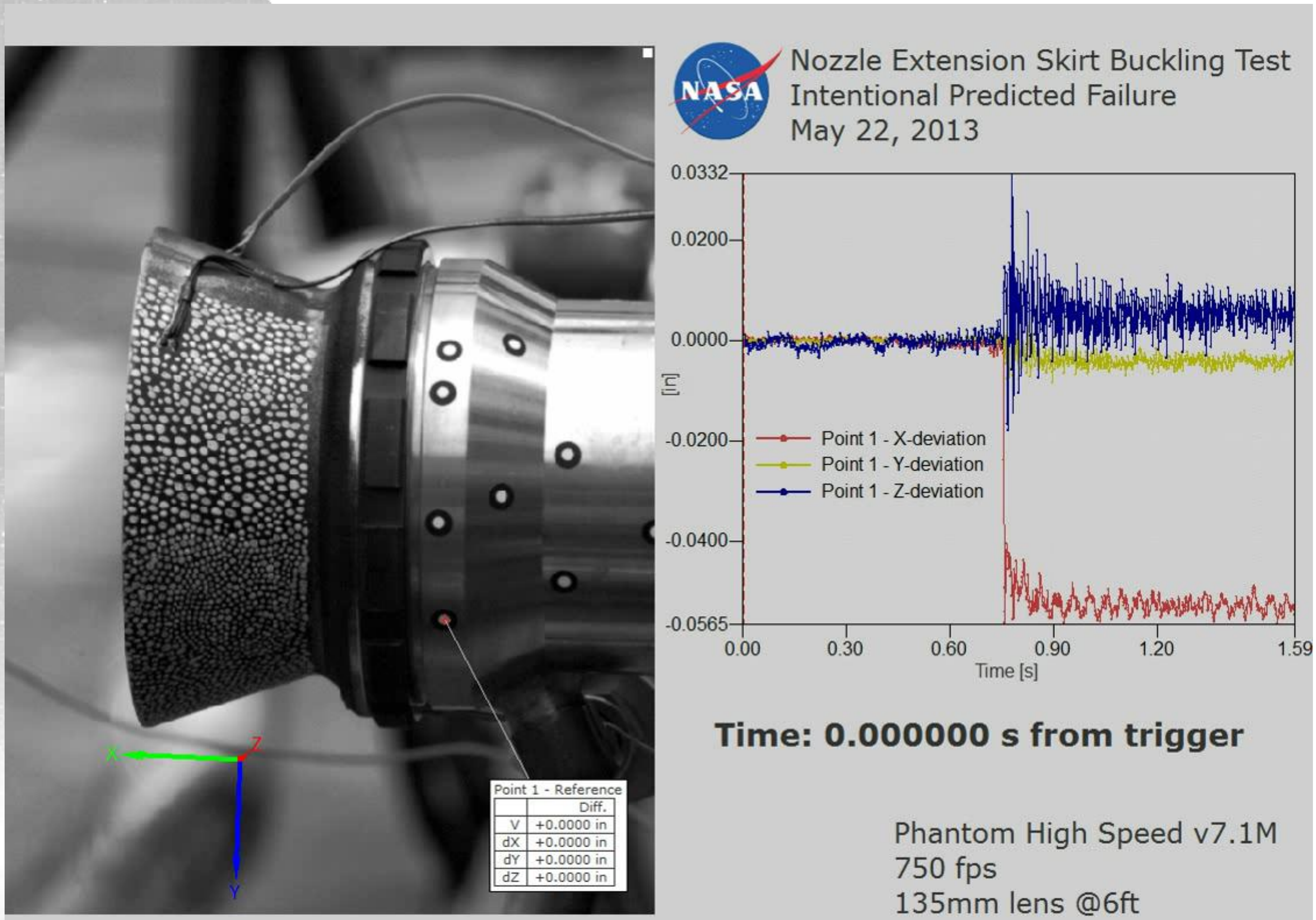




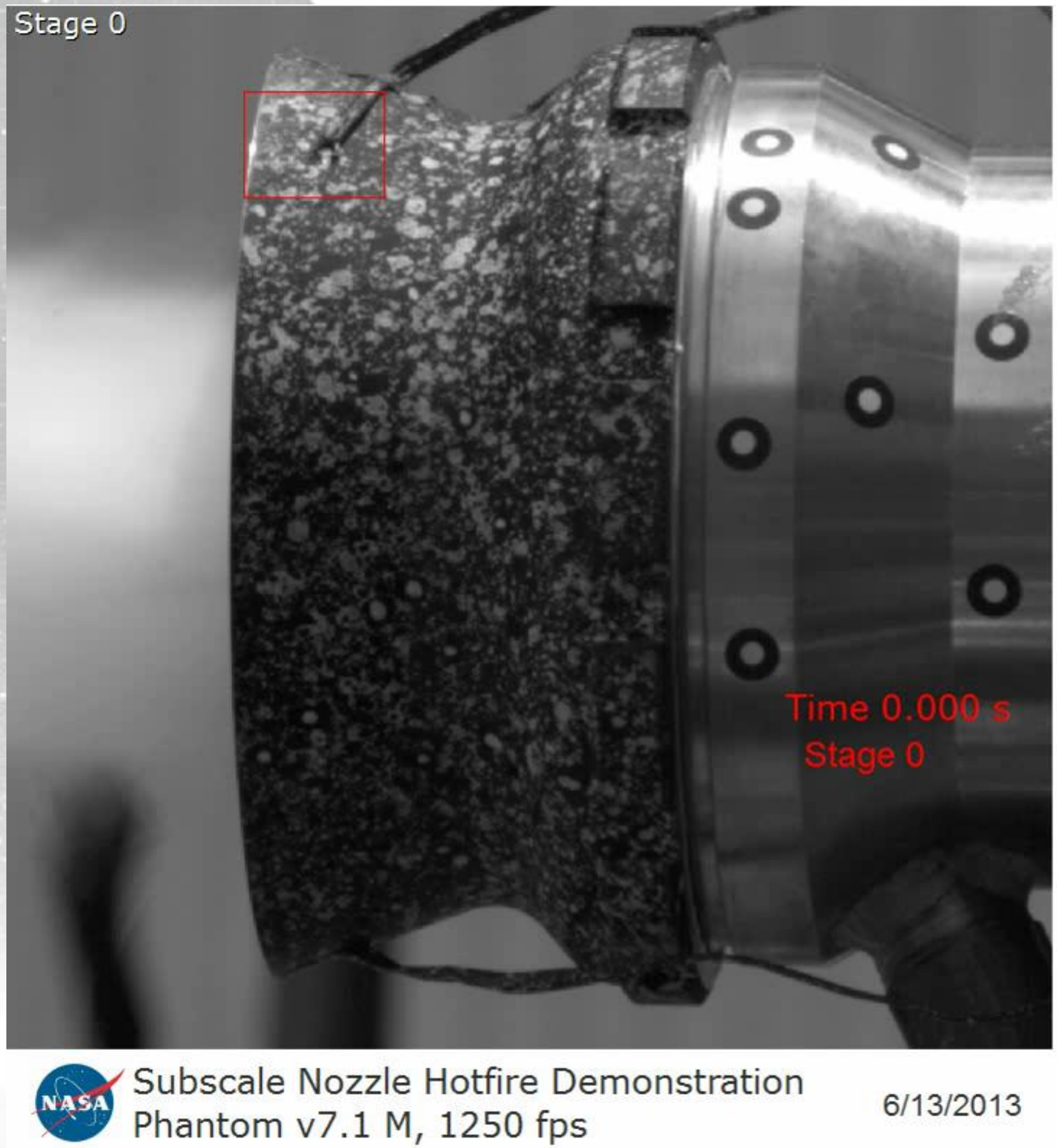
Additive Manufactured Radiative Cooled Nozzle Extension

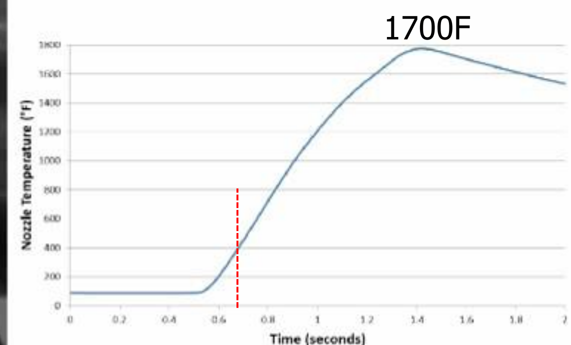
Test Photos and Data Collection:
Paul Gradl
Gilbert Handley
Sandy Elam Greene

Bench Testing Doesn’t Always Translate into the Field…



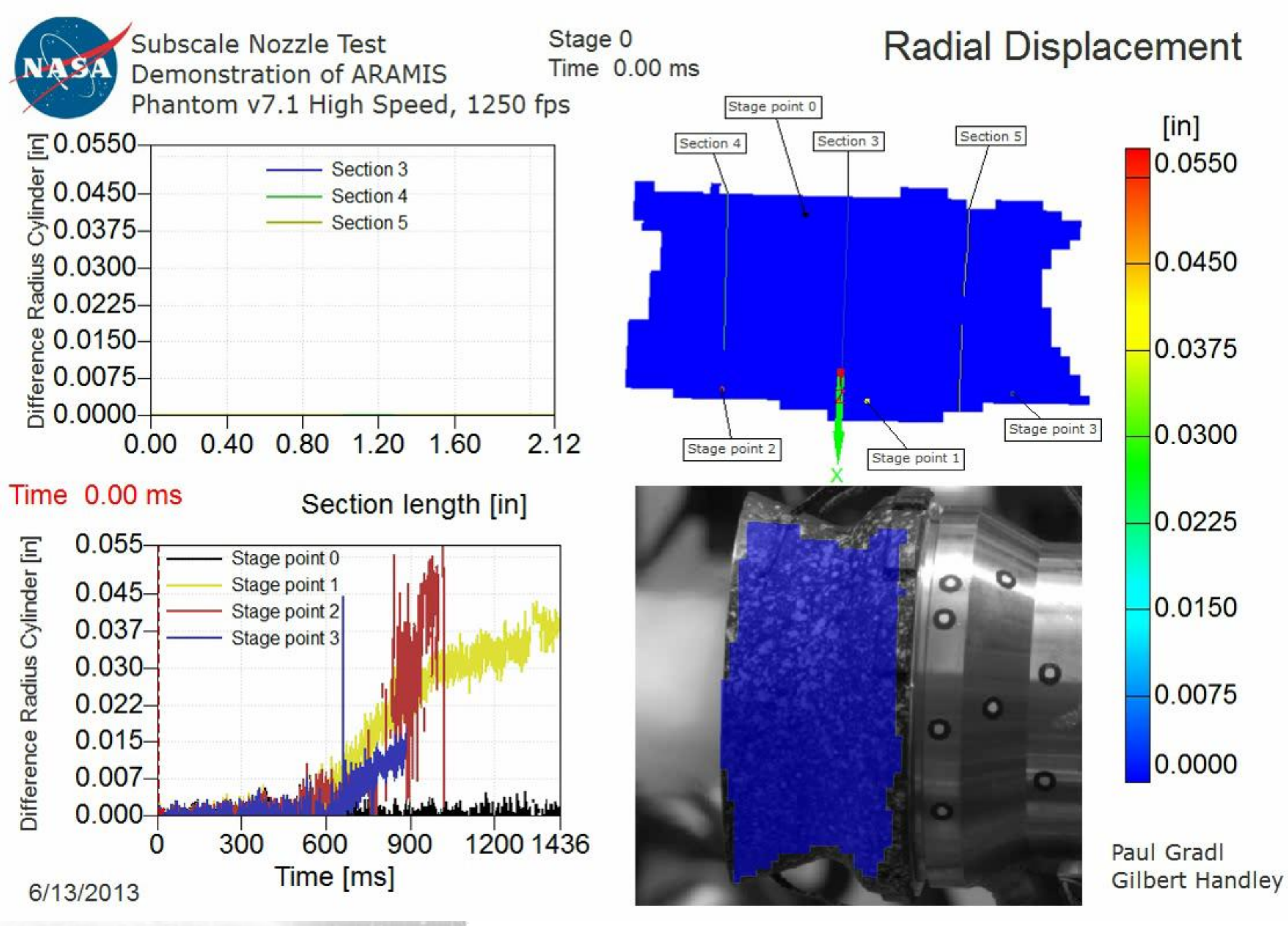
Motivation to Develop Technique



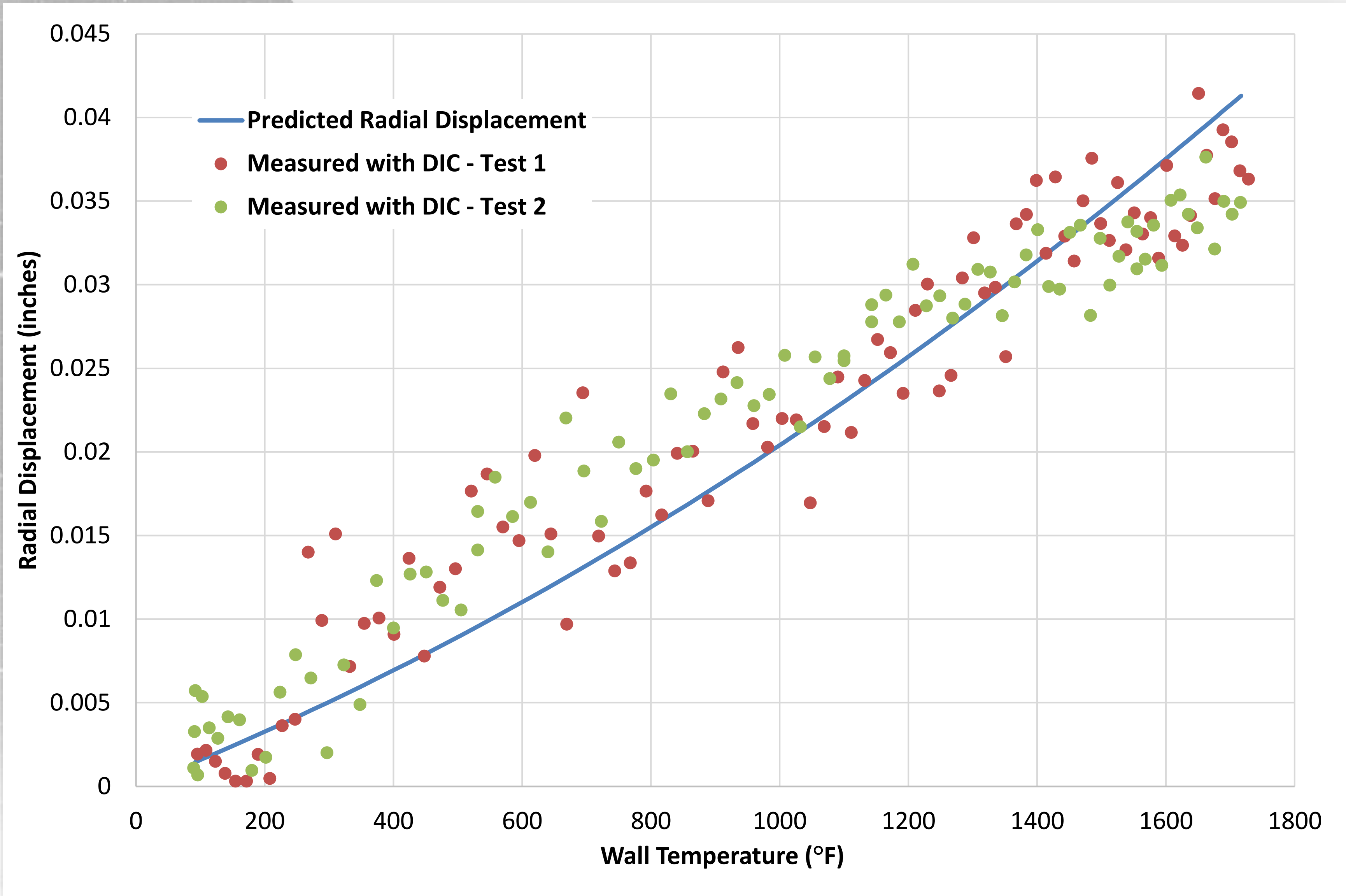


Strain Gage Failure at ~400F

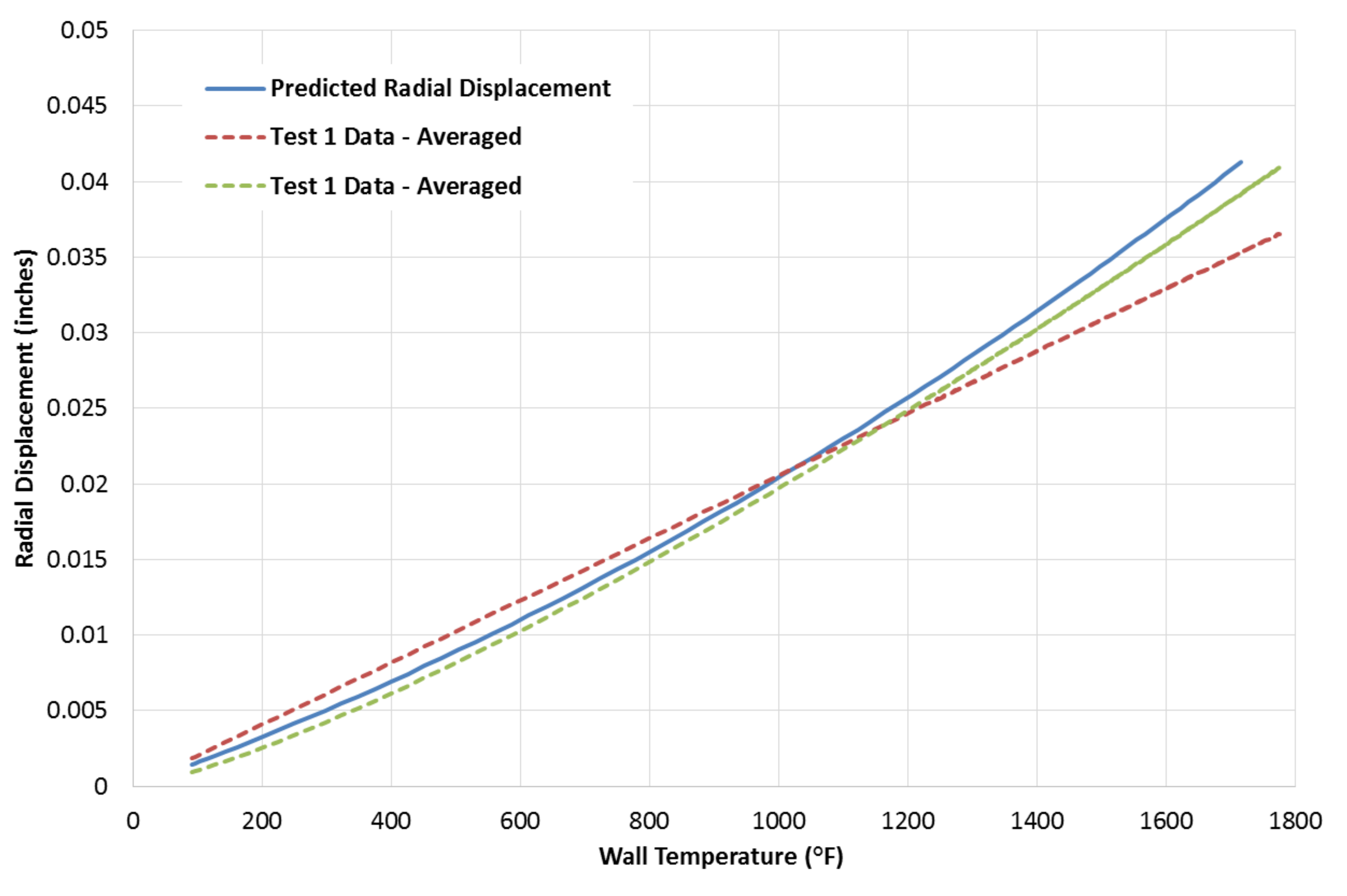
Subscale Hotfire Testing on Nozzle



Subscale Hotfire Testing – Data Analysis



Subscale Hotfire Testing – Averaged Data



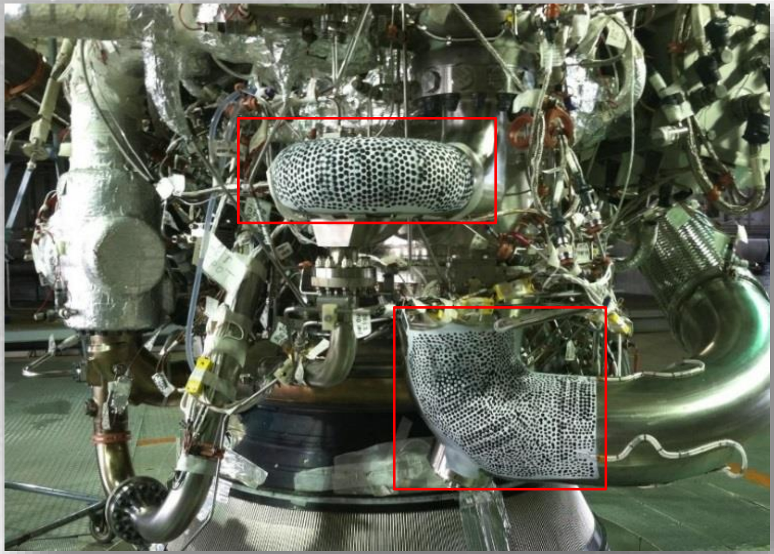
Optical test data tracking closely with predictions; error grows at elevated temperatures

Large Scale D.I.C. for Engine Hotfire Testing

MSFC has developed new optical measurement techniques to augment or replace traditional gages in harsh environment engine testing or manufacturing operations

Stereo high-speed cameras measure full-surface displacements and strains using "speckle pattern" (calibrated triangulation)

- Leveraged basic techniques from NESC Shell Buckling Test and NASA & industry experts
- Developed speckle pattern and initial vibration damping in subscale hotfire testing at MSFC
- J-2X provided the test-bed environment to develop camera stability damping
- Industry-first attempt for high temperature, high vibration environments where traditional gages do not operate reliably



Stereo Cameras installed and Speckle Pattern Applied at Stennis A1 Stand

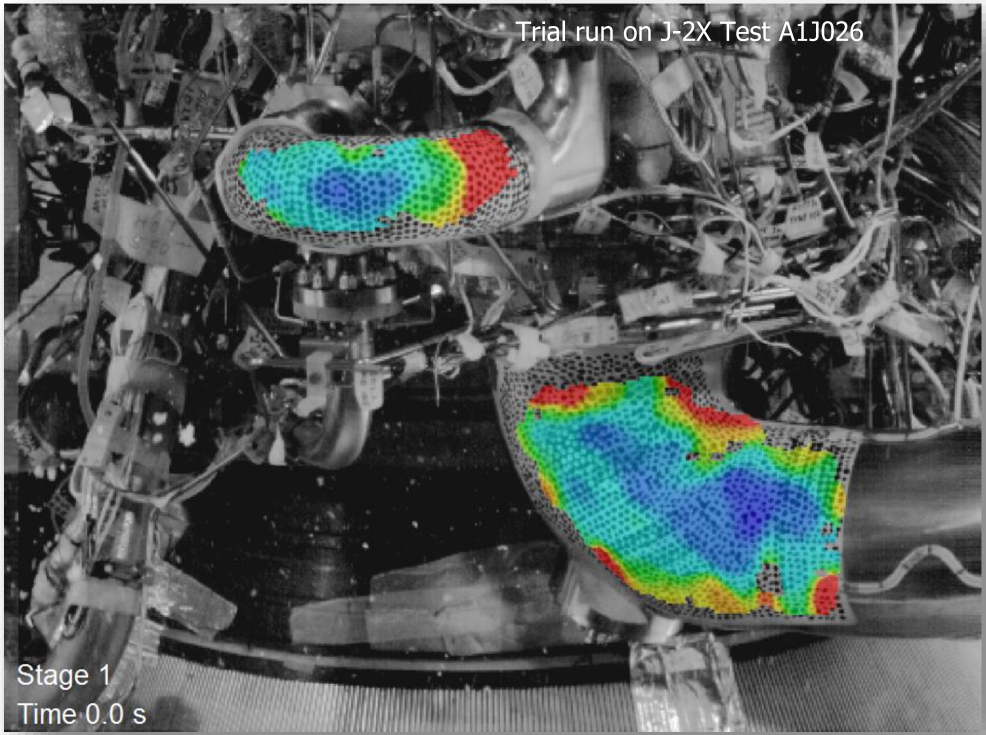
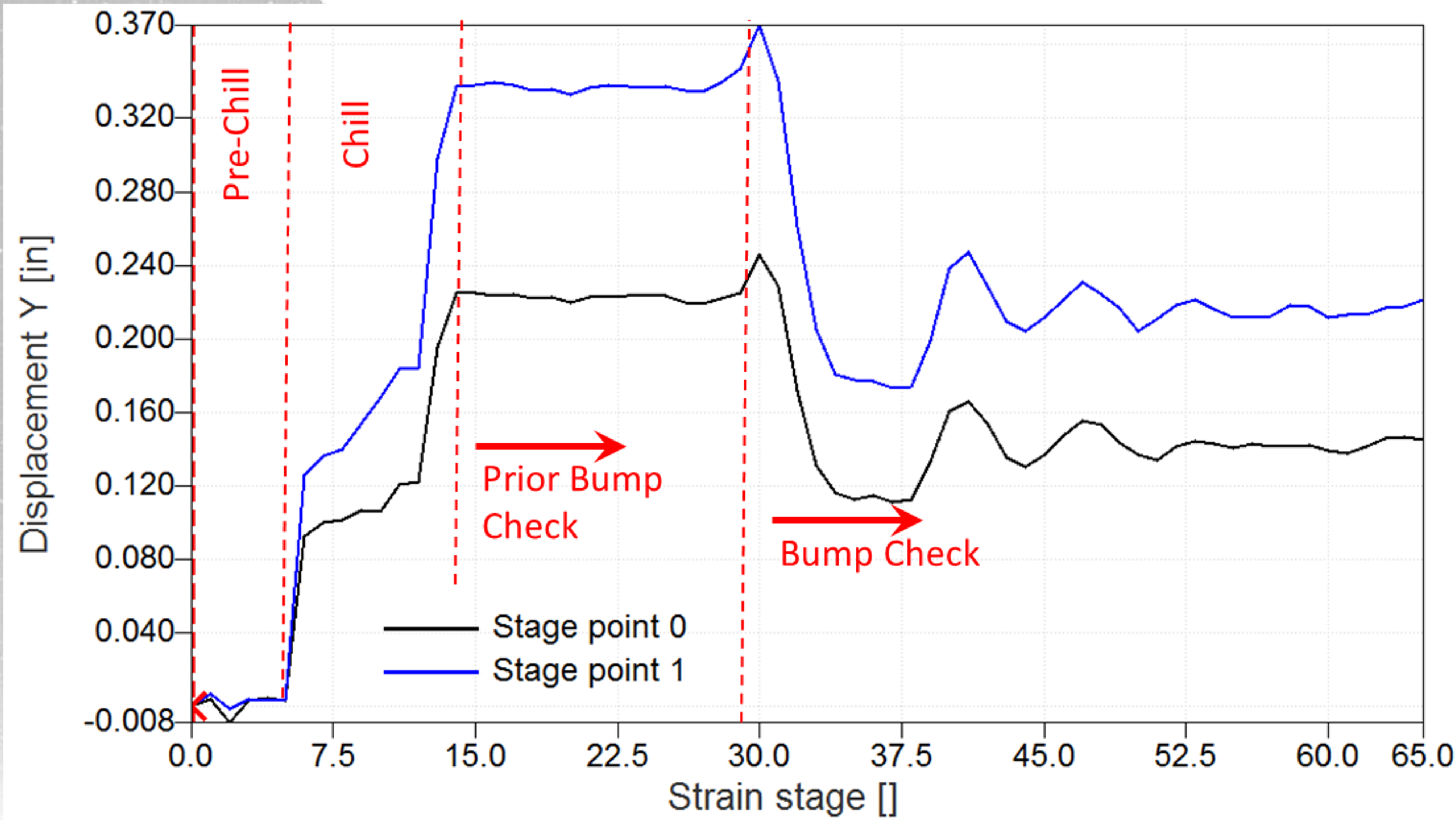


Photo Credit: Dan Goade

Test Data Collection:
Paul Gradl, Gilbert Handley, Brian West

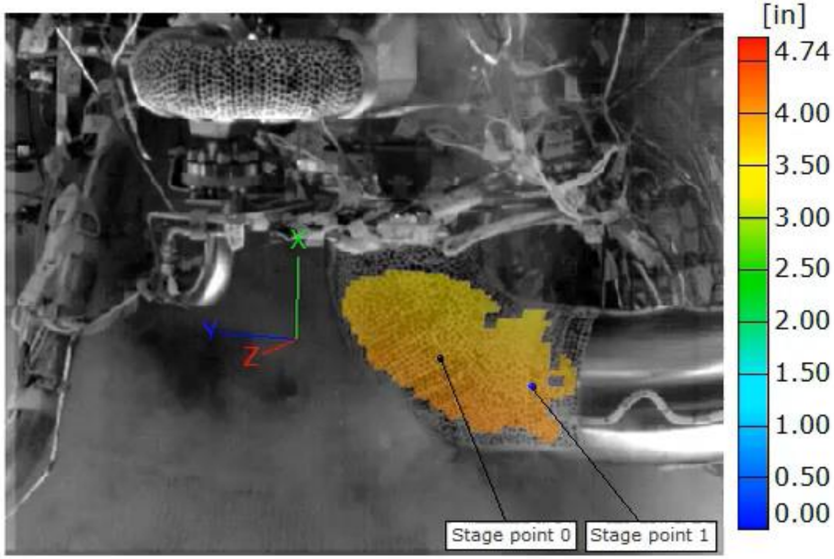
ARAMIS high speed cameras

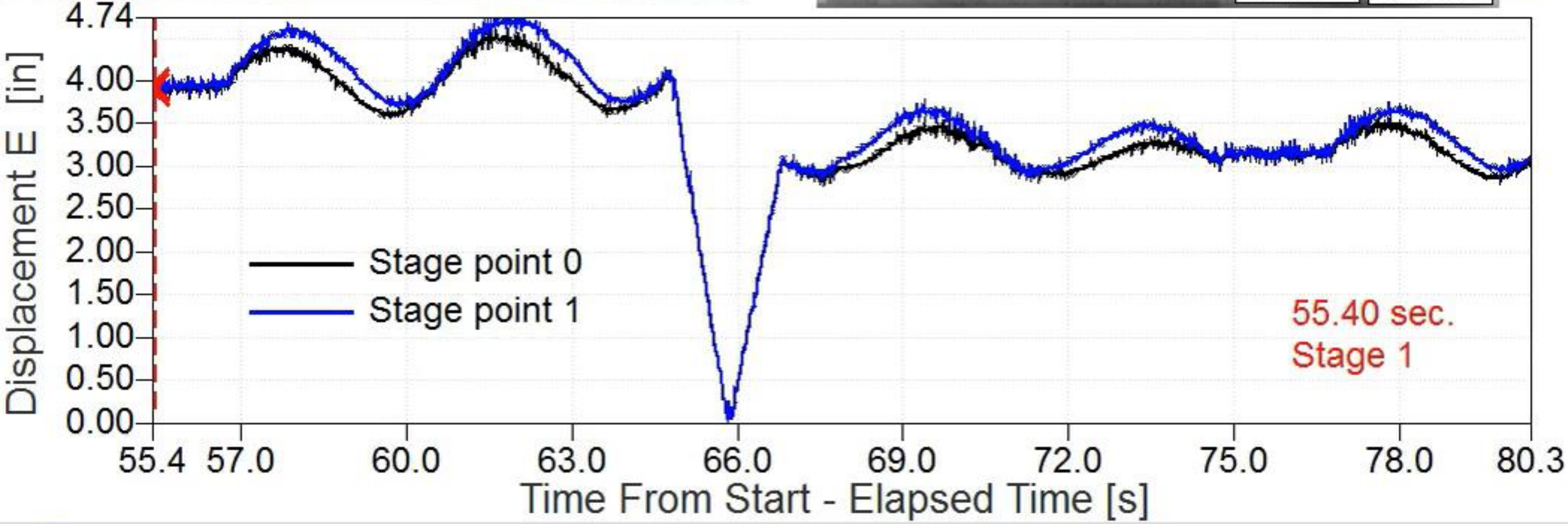
Engine Movement and Strains during Pre-test Ops



Ability to track engine during all chill and gimbal checkout operations

ARAMIS Full Surface Strain Measurement Proof of Concept Displacement during A1J028 Test



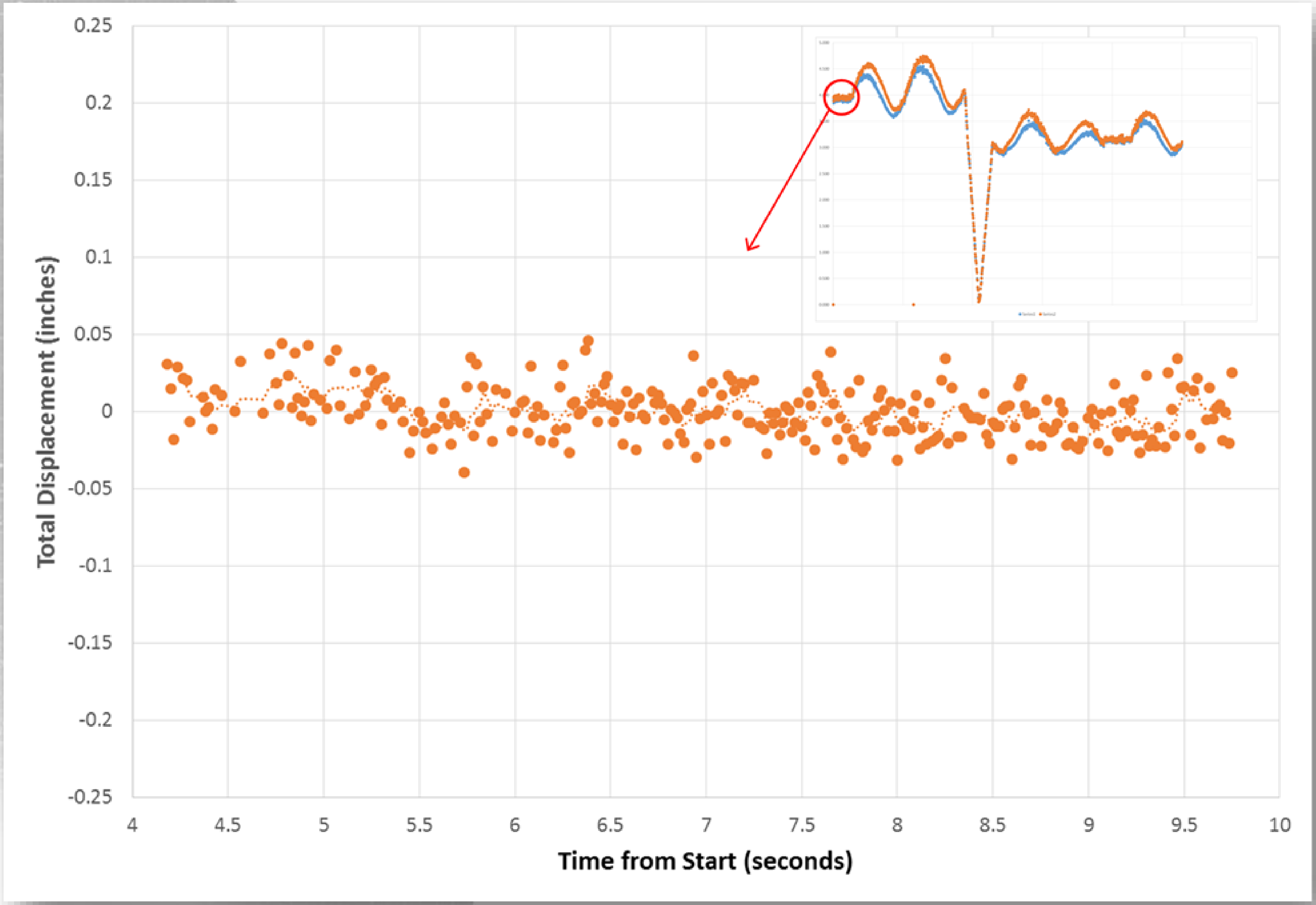


ARAMIS Trial on J-2X A1J028

Paul Gradl
Gilbert Handley

Displacement E (Total X, Y, Z)

Error Associated With Measurements During Hotfire



Conclusions and Future Work

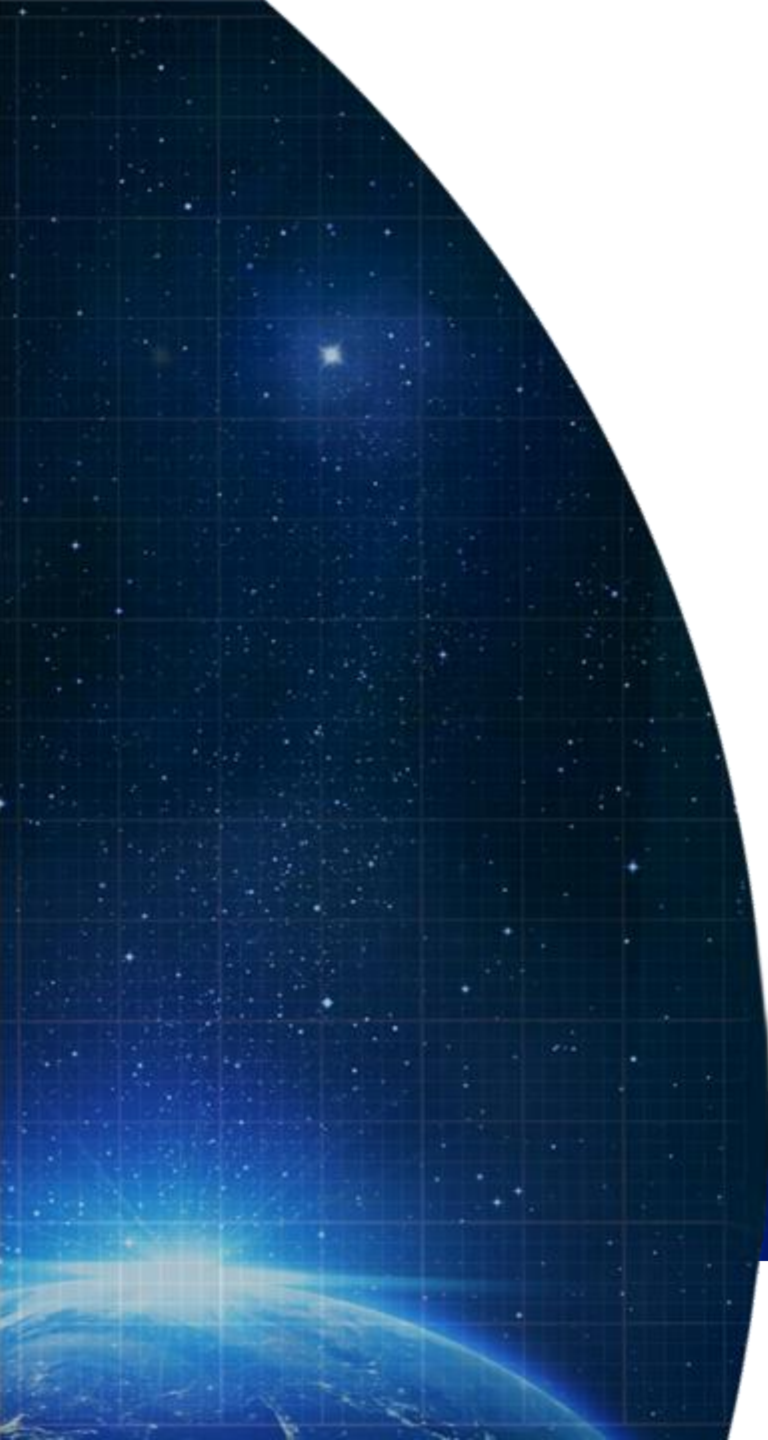
NASA MSFC has advanced a series of dynamic digital image correlation techniques for use during hotfire engine testing

- Subscale and full scale testing and analysis has demonstrated feasibility to accurately determine local and global displacements and surface strains

NASA will continue to advance this technology for rocket engine testing, subscale testing, component testing and bench top testing

- Replace traditional measurement systems
- Integrate with modern analysis tools
- Combine advanced techniques such as IR thermography and digital image correlation
- Continue to research and advance techniques for elevated temperature applications

Share lessons learned with industry and government through technical papers and presentations



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